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SOME FURTHER THOUGHTS ON TEMPORARY THRESHOLD SHIFT.(U)
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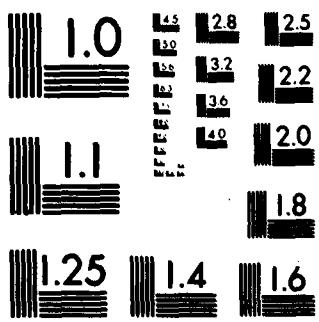

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SOME FURTHER THOUGHTS ON TEMPORARY THRESHOLD SHIFT

by

K. R. Maslen

SUMMARY

In a recent memorandum an attempt was made to explain the growth and recovery of Temporary Threshold Shift (TTS) as due to exponential shifts of the threshold pressure. Agreement with published results for continuous exposure to noise was reasonably good, but not good for intermittent exposures. It was suggested that this might be due to the fact that only averaged results were available. Some individual results have recently appeared, and these are compared with the pressure theory in this paper. The agreement is reasonably good considering the errors inherent in threshold measurements.

In addition, some further calculations on intermittent exposure are presented, and the possibility of error due to delays between the end of an exposure and the measurement of threshold is briefly discussed.

1 INTRODUCTION

In a recent paper[1] I attempted to explain the form of growth and recovery curves of TTS on the assumption that the pressure threshold varies exponentially during exposure to noise and in recovery after such exposures. On the whole, the theory appeared to agree fairly well with published data on individuals, when the shift was due to continuous exposure; but agreement was not very good when averaged data were considered, it was suggested because the wide variation between individuals disguised the true processes. When intermittent exposures were studied, poor agreement was found; but at that time, only averaged data had been found. Recently, however, Tobias[2] has published some data relating to individuals, and in this Memorandum, these data are compared with the theory (section 2).

With the support for the theory that this analysis gives, it was thought useful to do some further calculations on the ultimate threshold shifts to be expected when subjects are exposed for alternating equal short periods to different levels of one kind of noise, and these calculations are described in section 3. In the earlier paper, it was assumed throughout that measurements of thresholds could be made immediately after the cessation of exposure. This assumption is open to objection in that, in real life, there is always a lapse of time between the two events. The possible errors in the theory due to this lapse of time are discussed in section 4.

2 INTERMITTENT EXPOSURES: THEORY COMPARED WITH TOBIAS' DATA[2]

In his experiment, Tobias exposed nine subjects to repeated cycles each consisting of 3 minutes of a 4 kHz tone at 110 dB re 20 μPa and a rest period. Each test consisted of five or six cycles with the same rest period, and each subject was tested with rest periods varying from 5 to 45 minutes. TTS at 5.66 kHz was measured 30 seconds and 2 minutes after the end of each exposure, and the individual results for the two most susceptible subjects were reported. Subject 1 gave such erratic results that attempts to match them with theory would be very largely guesswork, and, as has been pointed out, see section 4, measurements of TTS earlier than 2 minutes are not regarded as reliable. Hence, one set of results only, that for subject 2 at 2 minutes, can be dealt with.

These are re-plotted in Fig 1 - the original plot is on a very small scale, so accurate reproduction is not guaranteed. Each plot is labelled with the inter-stimulus interval (ISI).

There appears to be no reason why the TTS after the first exposure should be affected by the ISI, hence the variation among the first measurements gives an

indication of the probable errors. The measurements are 12, 10, 7, 6, 7 and 12, giving a mean of 9 dB and a standard deviation of 2.7 dB. The mean plus and minus 1 standard deviation is shown as a bar in Fig 1.

Now, following the analysis of Ref 1, it can be shown that the shift after the nth exposure, on the exponential pressure threshold shift theory, is D_n dB, given by

$$D_n = 20 \log x_n$$

where
$$x_n = \left\{x_1\left[1 - y^{n(q+1)}\right] - y^{q+1} + y^{n(q+1)}\right\} \Big/ \left\{1 - y^{(q+1)}\right\} \qquad \text{for } n > 1$$
$$= 1 + (x_1 - 1)(1 - y^{n(q+1)}) \big/ (1 - y^{(q+1)}) \qquad (1)$$

$D_1 = 20 \log x_1$, is the shift after the first exposure

q is the ratio of resting time to time of exposure (ISI/3),

$y = e^{-(t/T)}$ where t is the exposure time (3 minutes)

and T is the time constant of the response.

This implies that the ultimate threshold for continuous exposure to the noise would be D' dB,

where
$$D' = 20 \log\{(x_1 - y)/(1 - y)\} \qquad (2)$$

and that the ultimate threshold if the intermittent exposure were continued indefinitely would be D'' dB,

where
$$D'' = 20 \log \left[(x_1 - y^{(q+1)}) \big/ (1 - y^{(q+1)})\right] . \qquad (3)$$

In this case, we had already determined that $D_1 = 9$, and by a process of trial and error it appeared that y was approximately 0.98. Thus D_n can be calculated for all values of n . Also, since $y = \exp(-3/T)$, we have a value of 148 minutes for T , which is of the expected order, and a value of 39.3 dB for D'.

The values calculated for the threshold after each exposure are given in Table 1 below, and plotted in Fig 1.

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Calculated TTS after successive exposures to noise

	Rest time (min)	(q + 1)	D_2	D_3	D_4	D_5	D_6	D"
1	5	8/3	13.1	15.8	17.8	19.3	20.5	31.0
2	10	13/3	13.0	15.6	17.4	18.8	19.9	27.1
3	15	6	12.9	15.4	17.1	18.3	19.3	24.6
4	20	23/3	12.8	15.1	16.7	17.9	18.8	22.7
5	30	11	12.6	14.7	16.1	17.0	17.8	20.1
6	45	16	12.3	14.1	15.2	16.0	16.4	17.6

Although the agreement between the experimental and calculated points is by no means perfect, it is quite as good as could be expected having regard to the inaccuracies inherent in measuring thresholds. Since all the measurements are referred to the threshold before the first exposure, a systematic error throughout any one case is possible, and it will be seen that in cases 1, 5 and 6 agreement would be improved by postulating systematic errors of 3, − 2 and 3 dB respectively, such errors being well within the probable errors since the sd for the first measurement is 2.7 dB.

Thus, for this one individual case, it can be said that the shifts for one case of intermittent exposure to noise are not inconsistent with the exponential shift of threshold pressure.

3 ULTIMATE SHIFTS FOR ALTERNATING EXPOSURES TO EQUAL SHORT PERIODS OF ONE KIND OF NOISE AT DIFFERENT LEVELS

This kind of noise exposure is often used in experiments, and it seemed desirable to extend the analysis given in Ref 1 to show how the ultimate threshold shift is linked with the difference between the two levels. It was shown that, if continuous exposure to the two levels of noise L and L' dB would lead ultimately to threshold shifts at a particular frequency of D and D' dB, alternating exposure to the two levels for short equal periods would lead to a threshold shift

$$D'' = 20 \log\left\{[\text{antilog}(D/20) + \text{antilog}(D'/20)]/2\right\} . \tag{4}$$

It was also shown that the shift D is given by

$$D = 20 \log\left\{1 + \text{antilog}[(L - L_c)/10]\right\} \tag{5}$$

and similarly for D' ,

where L_c is a constant for the type of exposure and the test frequency. Hence, combining equations (4) and (5), we find that the ultimate shift D'' due to the alternating exposure is

$$\begin{aligned} D'' &= 20 \log\left\{1 + \{\text{antilog}[(L - L_c)/10] + [\text{antilog}(L' - L_c)/10]\}/2\right\} \\ &= 20 \log\left\{1 + \text{antilog}[(L - L_c)/10]\{1 + \text{antilog}[(L' - L)/10]\}/2\right\} \end{aligned} \quad . \tag{6}$$

Fig 2 shows the variation of D'' for constant values of $(L - L_c)$ and values of $(L' - L)$ ranging from -20 to 20 dB.

4 CHANGE OF THRESHOLD BETWEEN END OF EXPOSURE AND MEASUREMENT

An objection to the analysis of Ref 1 could be made in that the results were presented as though TTS could be measured immediately at the conclusion of an exposure to noise whereas, in fact, there must always be some delay. The following is a brief assessment of the order of the error due to the time lapse.

On the exponential pressure theory, the threshold in dB at time t after the end of the exposure is given by

$$D = 20 \log\left\{1 + \exp(-t/T)[\text{antilog}(D'/20) - 1]\right\} \tag{7}$$

where D' dB is the initial shift and T is the time constant.

Comparison with published results suggests that T is generally of the order of several hundred minutes, though occasionally a time constant of the order of 30 minutes may occur[1]. Hence, if, as is usual, TTS is measured first when $t = 2$ minutes, t/T is small for this measurement, certainly less than about 0.1. For such values of t/T, it can be shown that

$$\begin{aligned} D' - D &\triangleq 20 \log e(t/T)[1 - \text{antilog}(-D'/20)] \\ &= 8.69(t/T)[1 - \text{antilog}(-D'/20)] < 8.69(t/T) \quad . \end{aligned} \tag{8}$$

Thus the decrease of threshold in the first 2 minutes after an exposure, according to the theory, is always less than 1 dB - hardly important having regard to the errors inherent in threshold measurement.

It may be said that this statement does not correlate well with some experiments, where shifts of as much as 5 dB have been reported in the first 2 minutes[2]. But some very odd effects appear to occur immediately after the

cessation of exposure to noise, and it was recommended by Burns (Ref 3, p 201) that no measurements of TTS should be made before the lapse of 2 minutes.

5 CONCLUSION

Analysis of recent data[2] on threshold shift in an individual due to intermittent exposure to noise has shown quite good agreement with the theory that TTS is an exponential function of the pressure threshold. This adds further support to the arguments presented in a recent memorandum[1].

In addition, the ultimate shifts due to alternating exposure to equal short periods of one kind of noise at different levels has been calculated and presented graphically. Also the probable errors due to lapse of time between the cessation of the noise exposure and measurement of the threshold are discussed, and it is suggested that such errors are well within probable experimental errors.

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REFERENCES

No.	Author	Title, etc
1	K.R. Maslen	Towards a better understanding of temporary threshold shift of hearing. RAE Technical Memorandum FS 319 (1980)
2	J.V. Tobias	Interstimulus interval as it affects temporary threshold shift in serial presentation of loud tones. USA FAA Doc AM-79-16 T79-4489
3	W. Burns	Noise and man. (Second edition) London, John Murray (1973)

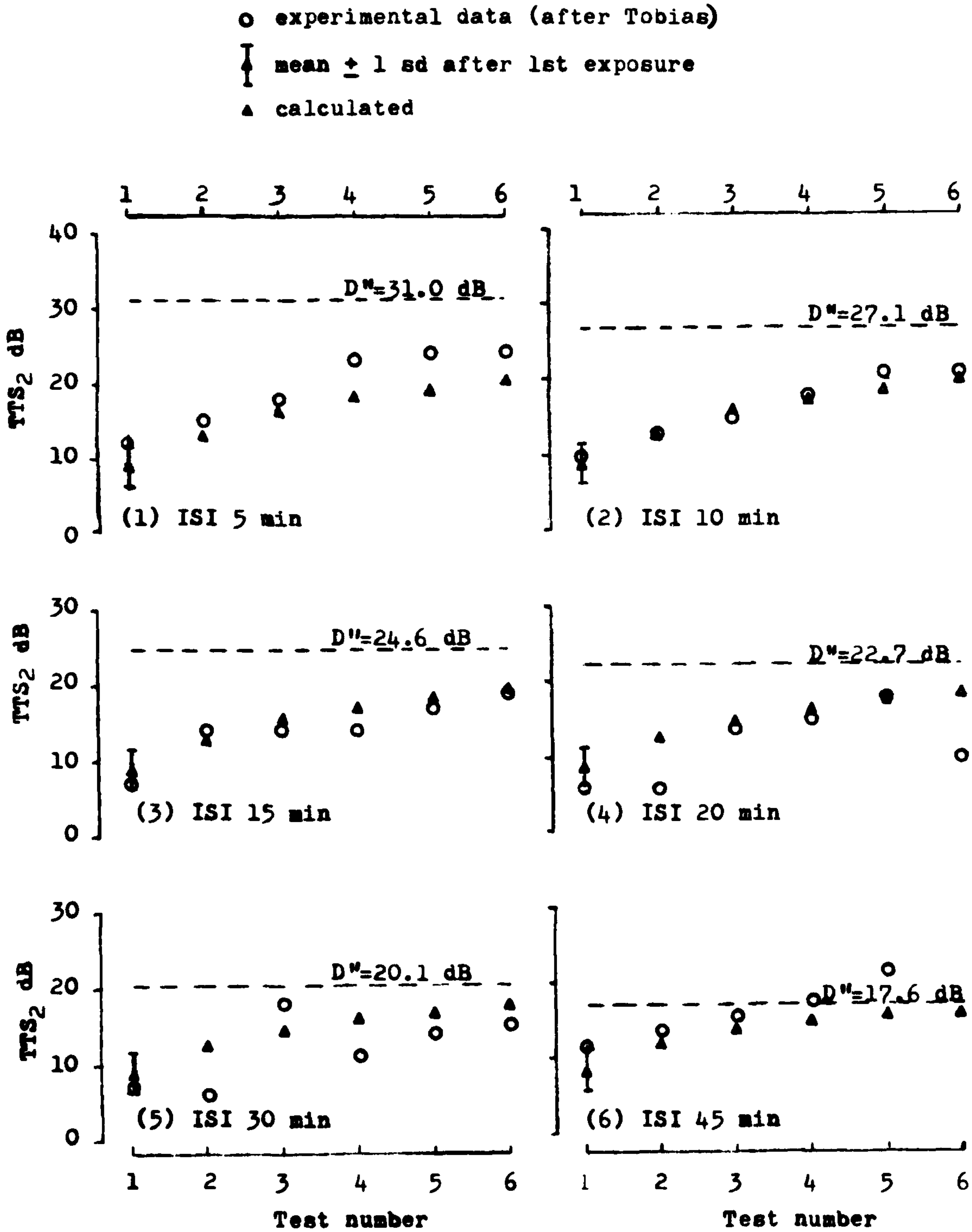

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Fig 1 Variation of threshold during intermittent exposure (theory compared with data from Tobias[2])

Fig 2

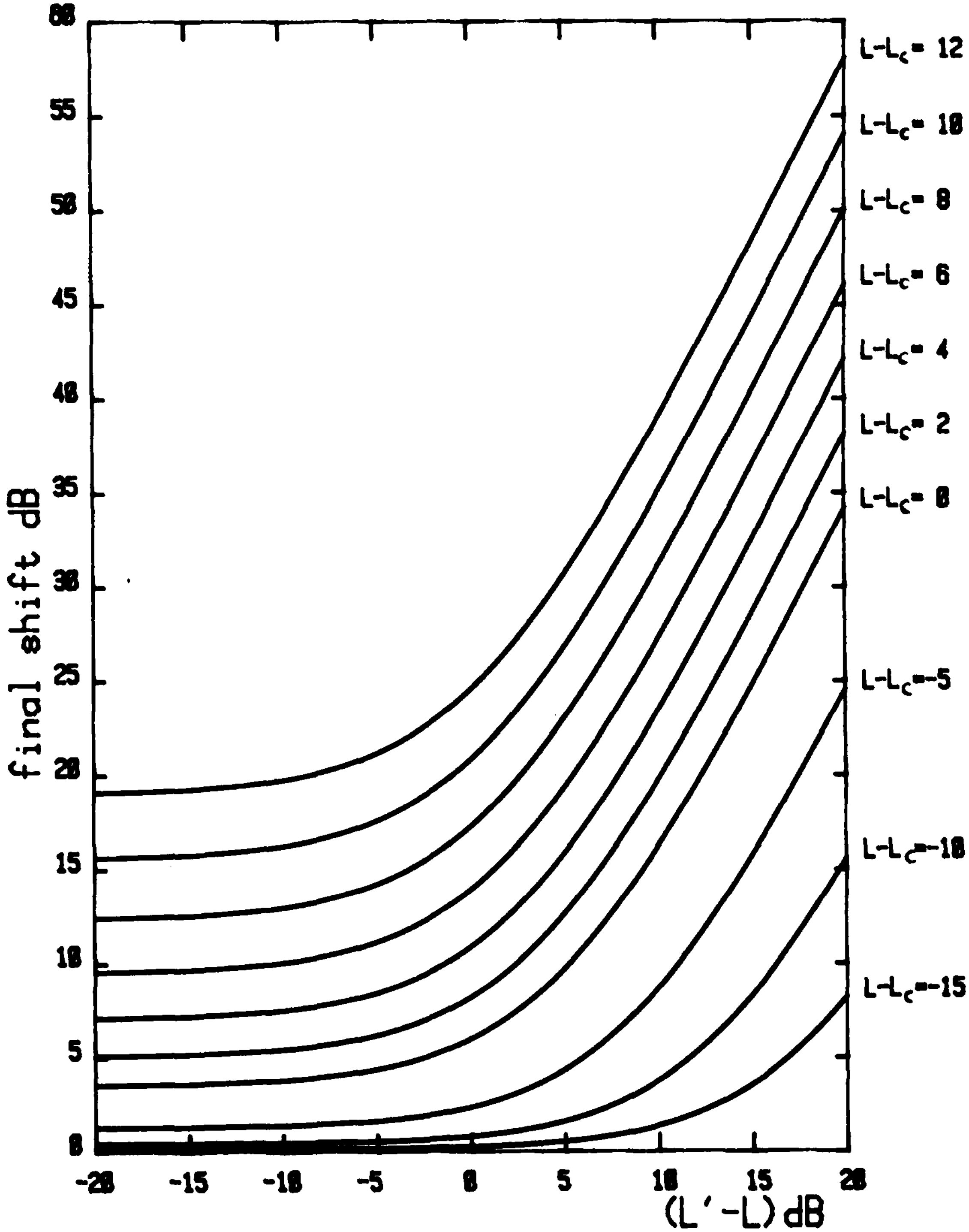

Fig 2 Variation of ultimate threshold with level differences for alternating equal short exposures

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[illegible] exposure are presented, [illegible] the end of an exposure and the [illegible]